A Probabilistic Approach to Uncertainty Quantification with Limited Information

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Many safety assessments rely on probabilistic characterizations about which there is incomplete knowledge. For example, a given system may depend upon the time to failure of a piece of equipment for which no failures have actually been observed. In such a case, analysts are faced with the task of developing a failure model for the equipment in question, having very limited knowledge about either the correct form of the failure distribution or the parameters that characterize the distribution. They may assume that the process conforms to a Weibull or log-normal distribution or that it can be characterized by a particular mean or variance, but those assumptions impart more knowledge to the analysis than is actually available. To address this challenge, we propose a method where random variables comprising equivalence classes constrained by the available information are approximated using polynomial chaos expansions (PCEs). The PCE approximations are based on rigorous mathematical concepts developed from functional analysis and measure theory. The method has been codified in a computational tool, AVOCET, and has been applied successfully to example problems. Results indicate that it should be applicable to a broad range of engineering problems that are characterized by both irreducible and reducible uncertainty.